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P36950-/JED/JAL

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P01/7700 0.00-0406782.3 NONE

3. Full name, address and postcode of the or of
each applicant (*underline all surnames*)Downhole Products plc
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country/state of its incorporation

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4. Title of the invention

"Apparatus"

5. Name of your agent (*if you have one*)

Murgitroyd & Company

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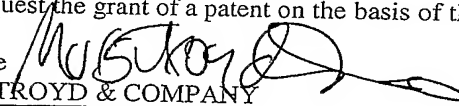
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1 "Apparatus"

2

3 The present invention relates to apparatus for
4 mobilising drill cuttings in an oil or gas well.

5

6 The art of drilling wellbores for recovery of oil
7 and gas is well known. One particular problem faced
8 by this art is the removal of cuttings from the well
9 as they are generated by the action of the drill bit
10 cutting into the formation. The cuttings need to be
11 removed from the bit and conveyed back to surface as
12 efficiently as possible, as their persistence in the
13 wellbore hampers drilling activity, and tends to
14 reduce the productivity of the well.

15

16 Cuttings are washed back to surface by drilling mud
17 or fluid pumped down the string, out through the
18 bit, and back up the annulus surrounding the string.
19 This solution is generally satisfactory, but in long
20 and deviated wells we have found that cuttings still
21 tend to clump and impede the drilling activity, or
22 the production of the well.

1 According to the present invention there is provided
2 apparatus for mobilising drill cuttings in a well,
3 the apparatus comprising at least one vane, and two
4 or more blades defining at least one fluid conduit
5 between adjacent blades, the blades being configured
6 to create a pressure difference in fluid flowing
7 through the conduit, and the blades and vane being
8 rotatable relative to one another.

9
10 The apparatus typically comprises a sleeve or
11 collar, which is typically tubular and is adapted to
12 fit over a string in the well. The string can be a
13 tubing string, drill string, or casing string etc.
14 Typically the vanes are provided on the sleeve.

15
16 Typically the blades are mounted on a bushing that
17 is rotatably mounted on the sleeve.

18
19 However, in certain simple embodiments, it is
20 sufficient to provide the vanes direct on the tubing
21 string (or on a sleeve attached to the string) and
22 to provide the blades on an adjacent part of the
23 string, or on a separate sleeve attached thereto, so
24 that the blade-bearing bushing is not directly
25 attached to the vanes-bearing sleeve.

26
27 Typically the sleeve is adapted for attachment to a
28 drill string, and the fixing means typically
29 comprises a clamp means such as an annular clamp to
30 fix the sleeve over the outer surface of the drill
31 pipe. However, the sleeve may equally attach to
32 casing or any other oilfield tubular goods.

1
2 The vanes can be carried direct on the sleeve, or in
3 some embodiments can be provided on a separate
4 bushing rotationally (or otherwise) affixed to the
5 sleeve. The vanes typically rotate with the drill
6 string in normal rotary drilling operations as they
7 are typically rotationally fixed to the drill
8 string. The rotation of the vanes agitates the
9 fluid surrounding the apparatus, and creates thrust
10 tending to drive the fluid past the sleeve.
11 The blades of the bushing typically create a
12 pressure drop in the fluid as it flows past the
13 apparatus, driven by the rotation of the vane(s).
14
15 Typically the bushing is free to rotate relative to
16 the sleeve, which is affixed to the drill string.
17 Thus, upon rotation of the drill string (or casing)
18 during normal rotary drilling, the bushing typically
19 remains stationary relative to the wellbore, while
20 the drill string rotates.
21
22 Typically the blades on the bushing project radially
23 outward to a greater extent than the vanes of the
24 sleeve, so that the radially outermost surface of
25 the blades contacts the inner surface of the bore
26 within which the string is located, and this
27 centralises the sleeve within the bore. In
28 preferred embodiments, the vanes are radially lower
29 than the blades, and can freely rotate within the
30 bore, as the higher blades provide a stand off
31 against the inner surface of the bore. The bore can
32 be the unlined wellbore, or can be the bore of

1 casing, liner or other tubing in which the apparatus
2 is located.

3
4 The blades typically have an asymmetric profile, and
5 in preferred embodiments the blades are shaped in
6 the form of foils, so that the fluid conduits
7 defined between adjacent blades on the bushing
8 change in profile. Typically the fluid conduits are
9 relatively narrow at a lower end (nearest the drill
10 bit) and grow relatively wider toward the upper end
11 (furthest away from the bit). The increase in
12 dimension from the bottom of the channel to the top
13 causes a pressure drop in the fluid flowing through
14 the channel.

15
16 Typically the bushing can be formed from a rigid
17 material, such as hard rubber or metal. The sleeve
18 is typically formed from metal such as steel, alloy,
19 aluminium, etc.

20
21 The sleeve can have an annular body to fit around a
22 tubular or string of tubulars. The annular body can
23 have the vanes integrally formed with it, for
24 example by moulding the sleeve and vanes as a single
25 piece. In alternative (and preferred) embodiments,
26 the sleeve can have vane-receiving recesses therein
27 to receive and retain modular vanes, which can be
28 slotted in the recesses, and retained therein. This
29 has the advantage that several different sizes of
30 vanes can be used with a single sleeve.

31

1 Likewise, the blades on the bushing can be modular
2 and can be received within blade recesses in the
3 same manner.

4
5 The vanes are typically curved, and in preferred
6 embodiments they cross the axis of the sleeve. In
7 especially preferred embodiments they are configured
8 in a sinusoidal "lazy-s" shape and this helps to
9 agitate the fluid surrounding the apparatus during
10 rotation.

11
12 The invention also provides a drill cuttings
13 agitation assembly, comprising a tubular, a vane,
14 and at least two blades defining at least one fluid
15 conduit between adjacent blades, the blades being
16 configured to create a pressure difference in fluid
17 flowing through the conduit, and wherein the vane
18 and the blades are rotatable relative to one
19 another.

20
21 The invention also provides a method of agitating
22 drill fluid in an oil or gas well, the method
23 comprising passing the drill fluid past a vane
24 rotatable relative to at least two blades, which are
25 configured to create a pressure difference in the
26 fluid passing them, whereby a pressure difference is
27 created in the fluid as it passes the blades.

28
29 An embodiment of the invention will now be described
30 by way of example and with reference to the
31 accompanying drawings, in which:

32

1 Fig. 1 is a side view of apparatus according to
2 the present invention, mounted on a tubular;
3 Fig. 2 is a close up side view of the Fig 1
4 apparatus;
5 Fig. 3 is a side view of a sleeve of the Fig 1
6 apparatus;
7 Fig. 4 is a side view of a bushing of a bushing
8 of the Fig 1 apparatus;
9 Fig. 5 is a side view of a clamp of the Fig 1
10 apparatus;
11 Figs. 6 and 7 (respectively) plan and underside
12 views of the Fig 4 bushing;
13 Fig. 8 is a flat view of a bushing half shell;
14 Fig. 9 is a side view of a bushing blade;
15 Fig. 10 is a plan view of a sleeve;
16 Fig. 11 is a sectional view through a clamp;
17 Fig. 12 is an outer side view of a second
18 sleeve;
19 Fig. 13 is an inner side view of the second
20 sleeve;
21 Fig. 14 is a sectional view through the second
22 sleeve;
23 Fig. 15 is a perspective view of a modular vane
24 for the second sleeve;
25 Fig. 16 is an underneath view of the Fig 15
26 vane;
27 Fig. 17 is a plan view of the Fig 15 vane; and
28 Fig. 18 is a side view of the same vane.
29 Referring now to the drawings, apparatus for
30 mobilising drill cuttings in a well comprises a
31 sleeve 5, a bushing 7 and a clamp 9. All of these
32 components are generally tubular, but are axially

1 divided into two separate leaves that are hinged
2 together. The leaves of the sleeve 5 are hinged at
3 three locations 5h, and its two leaves pivot around
4 those hinges to enable the sleeve 5 to be opened and
5 closed around a tubular T such as drill pipe or
6 casing. The two halves of the sleeve are locked
7 together by one or more bolts 5b at a position
8 diametrically opposite to the hinge 5h, so that the
9 sleeve 5 can be tightly fastened to the tubular T by
10 means of the bolts.

11
12 The hinges 5h are located on an upper part of the
13 sleeve 5, beneath which is a bearing region 6 having
14 a reduced outer diameter as compared with the
15 nominal diameter of the upper region. An annular
16 groove 6g is formed on the lower end of the bearing
17 region 6, and a shoulder 6s divides the upper and
18 bearing regions of the sleeve.

19
20 The bushing 7 is also formed as two separate leaves
21 that are connected together at diametrically opposed
22 positions by interlocking castellations and
23 connecting pins 7p, about which the two leaves can
24 pivot. The two leaves of the bushing 7 are
25 typically closed around the bearing region 6 of the
26 sleeve, at which point the leaves are connected
27 together by inserting the pins 7p into axially
28 aligned bores on the interlocking castellations to
29 close and lock the bushing 7, so that the bushing 7
30 is connected to the sleeve 5.

31

1 After the bushing 7 has been locked in place around
2 the bearing region 6 of the sleeve 5, the clamp 9 is
3 then placed around the lower end of the bearing
4 region 6, so that an annular lip on the internal
5 surface of the clamp 9 engages in the external
6 annular groove 6g on the lower part of the bearing
7 region 6. The clamp 9 is then closed and fastened
8 by means of bolts (not shown) in the same manner as
9 the bolts 5b that lock the sleeve closed around the
10 tubular T.

11

12 When thus assembled, the tightening of the bolts in
13 the sleeve 5 and the clamp 9 securely connects the
14 sleeve to the tubular, so that the two are
15 rotationally connected, and thus the sleeve rotates
16 with the tubular.

17

18 The bushing 7 is fixed to the bearing area 6 of the
19 sleeve, and is prevented from axial movement by the
20 shoulder 6s above it, and the clamp 9 below it;
21 however, the bushing 7 is free to rotate around its
22 axis relative to the sleeve and the clamp, and the
23 tolerance of the outer diameter of the bearing
24 region 6 and the inner diameter of the bushing 7 are
25 chosen to permit a degree of play between the two,
26 and allow rotation of the bushing 7 around the axis
27 of the sleeve 5.

28

29 The sleeve 5 has vanes 12 mounted on the upper large
30 diameter section. As best shown in Fig. 10, two
31 vanes 12 are mounted on each leaf of the sleeve, and
32 the vanes are spaced apart on the circumference of

1 the assembled sleeve 5 at equal distances, so that
2 the vanes 12 are arranged in diametrically opposed
3 pairs.

4
5 The vanes 12 have a generally sinusoidal shape with
6 a lower scoop 12s, a generally axial mid-region 12m,
7 and an upper deflector portion 12d.

8
9 In side profile, the vanes 12 are generally arcuate
10 in the scoop and deflector regions, rising from the
11 plane of the sleeve 5 in a regular arc until a
12 plateau is reached at the mid-section 12m. Fig. 18
13 shows the side profile of a typical vane 12. The
14 vanes 12 project radially from the outer surface of
15 the sleeve 5, so as to create between adjacent vanes
16 12 a fluid path that is generally sinusoidal in
17 shape.

18
19 The bushing 7 has blades 15. Typically, there are
20 three blades arranged on each leaf of the bushing 7,
21 and typically these are circumferentially spaced at
22 equal distances, so that the blades 15 are arranged
23 in three diametrically opposed pairs, as best shown
24 in Figs. 6 and 7. Each blade 15 is arranged
25 generally parallel to the axis of the assembled
26 bushing 7, and in plan view, each blade 15 is in the
27 general shape of a foil or wing, as best shown in
28 Figs. 2 and 8. In detail, each blade 15 has a lower
29 end 15l that widens from the lowermost tip of the
30 blade to an apex 15a, from where it tapers through a
31 mid-section 15m, to an upper end 15u, and finally to
32 a slim point at the upper end. Shaping adjacent

1 blades like foils in this manner creates a flow path
2 between adjacent blades that rapidly narrows to a
3 throat at the level of the apex 15a of the blades,
4 and then gradually widens as the passage passes the
5 upper ends 15u of the blades.

6
7 As best shown in Fig. 9, the side profile of each
8 blade 15 rises from the plain of the bushing 7 at
9 the tips and is arcuate in the upper 15u and lower
10 15l ends, and forms a plateau in the mid-section
11 15m.

12
13 The nominal external diameter of the bushing 7 is
14 generally very close to the nominal external
15 diameter of the upper part of the sleeve 5, and also
16 matches that of the clamp 9, so that apart from the
17 vanes 12 and the blades 15, there are no upsets on
18 the outer surface of the apparatus.

19
20 The radial extent of the blades 15 typically exceeds
21 the radial extent of the vanes 12, so that the mid-
22 section 15m of the blades contacts the inner surface
23 of the bore in which the apparatus is deployed,
24 thereby spacing the vanes 12 from the inner surface
25 of the bore.

26
27 In preferred embodiments, the blades 15 are
28 integrally formed with the leaves of the bushing 7,
29 and in typical embodiments, the two leaves can be
30 cast or moulded each in a single piece with their
31 respective blades. Alternatively, the blades can be

1 formed separately and attached to the body of the
2 bushing 7 as required.

3
4 The vanes 12 can also be cast or moulded integrally
5 with the separate leaves of the sleeve, but in
6 preferred embodiments, the vanes 12 (and optionally
7 the blades 15) can be separately cast or otherwise
8 formed from the same or a different material, and
9 can be assembled with the sleeve prior to use in a
10 modular fashion.

11
12 One such arrangement is shown in Figs. 12 to 18.

13
14 In this embodiment, the sleeve 5 has a vane-
15 receiving portion 20, which comprises a region with
16 an increased inner diameter. Each vane 12 has a
17 base plate 12b attached to its radially innermost
18 face as shown in Fig. 15. The base plate 12b is
19 curved, with an outer diameter that matches the
20 inner diameter of a vane-receiving portion 20 of the
21 sleeve.

22
23 When the sleeve 5 is to be assembled with the
24 modular vanes 12, the radially outermost mid-portion
25 12m of each vane is offered to a vane-shaped slot 18
26 in the vane receiving portion 12, so that the mid-
27 portion 12m passes from the inner surface of the
28 sleeve 5 through the vane receiving slot 18, and
29 extends radially outward from the outer surface of
30 the sleeve 5. The curved radially outer face of the
31 base plate 12b of each vane 12 matches the inner
32 diameter of the vane receiving portion 20, and the

1 depth of each base plate 12b is chosen to match the
2 step between the nominal inner diameter of the
3 sleeve 5 and the nominal inner diameter of the vane
4 receiving portion 20, so that when the modular vanes
5 are assembled with the sleeve 5, the base plates 12b
6 are accommodated within the vane-receiving portion
7 20, and the inner diameter of the sleeve and base
8 place are contiguous. The assembled sleeve with
9 modular vanes 12 can then be clamped onto the
10 tubular T as previously described.

11
12 Modular vanes 12 give the advantage that worn vanes
13 can be replaced easily, and different sizes or
14 profiles of vanes 12 can be used with the same
15 sleeve body. Also, vanes of different materials or
16 properties can be provided on a generic sleeve 5,
17 and if desired, modular vanes 12 having different
18 characteristics can even be provided on the same
19 sleeve 5.

20
21 It will be appreciated that modular blades 15 can be
22 provided for the bushing 7 in the same way.

23
24 Typically the bushing 7 and blades 15 are formed
25 from a hard material such as a hard rubber or
26 plastic. Metals are also useful for the formation
27 of the bushing 7, and aluminium, zinc alloy, or
28 austempered ductile iron can be used for this
29 purpose.

30
31 The sleeve 5 and vanes 12 need not be formed from
32 the same material as the bushing 7 and blades 15,

1 and in preferred embodiments, metals or plastics can
2 be used for the vanes 12 and/or the sleeve 5.

3
4 In use, when the apparatus is clamped to a tubular T
5 such as a drill string that is being used to drill a
6 well, the device is typically deployed at regular
7 intervals along the bore, and can be used from a
8 position relatively close to the drill bit right up
9 to the top of the bore. The weight of the string T
10 typically forces the mid-portion 15m of the blades
11 15 against the inner surface of the wellbore, so
12 that the string is spaced away from the inner
13 surface of the wellbore by the radial extent of the
14 blades 15. Since the sleeve 5 is securely
15 rotationally fastened to the drill string T, the
16 sleeve 5 and hence the vanes 12 rotate in the
17 direction of arrow A in Fig. 1, ie clockwise when
18 viewed from the top of the string. However, since
19 the weight of the string is pressing the blades 15
20 against the inner surface of the wellbore, and since
21 the bushing 7 is rotatable on the bearing area 6,
22 the bushing 7 remains stationary relative to the
23 wellbore, and the sleeve and vanes 12 rotate
24 relative to the bushing 7 along with the string.

25
26 The radial dimensions of the blades 15 exceed those
27 of the vanes 12, and thus the vanes 12 are spaced
28 from the inner surface of the bore, and are not
29 impeded from rotating by contact with the inner
30 surface of the wellbore. The rotation of the vanes
31 12 and the speed of the string (typically 120-180
32 rpm with normal rotary drilling, but sometimes as

1 slow as 20 rpm with casing drilling) generates
2 turbulence in the drill fluid in the annulus between
3 the string and the wellbore. The sinusoidal
4 arrangement of the vanes 12 generates thrust in the
5 drill fluid in the region of the apparatus, and in
6 particular, the scoops 12s drive the drill fluid up
7 through the fluid passageways between adjacent
8 vanes, and the deflectors 12d accelerate it out of
9 the top of the fluid passage. In addition to
10 creating thrust in the fluid and pumping the fluid
11 from the lower end of the apparatus to the upper
12 end, this also creates turbulence in the fluid,
13 tending to break up clumps of drill cuttings, to
14 keep the fluid in a liquid phase.

15
16 The rapid rotation of the vanes 12 in the drill
17 fluid creates a pressure drop in the area between
18 the vanes 12 and the blades 15, which draws more
19 fluid up through the channels between adjacent
20 blades 15. As the fluid passes the apex 15a in the
21 channels between adjacent blades 15 on the
22 stationary bushing 7, it experiences a further
23 pressure drop created by the expansion in volume of
24 the fluid passageway as each blade narrows towards
25 its upper end. The pressure changes occurring as a
26 result of this speeds up fluid flow from the bit to
27 the surface, and also suspends cuttings in the
28 liquid phase, which makes it easier to return them
29 to surface.

30
31 An additional advantage of the non-rotating bushing
32 7 is that it reduces torque for rotation of the

1 string T within the hole, and the bearing surface
2 between the sleeve 5 and the bushing 7 is typically
3 lubricated by the drill fluid passing the apparatus.
4 In addition to this advantage, the smooth outer
5 surface of the blades 15, and particular the rounded
6 profile of the ends of the blades 15u and 15l, can
7 reduce drag while running in the hole, thereby also
8 reducing casing wear, and enhancing the penetration
9 of the drill bit. If the bushing 12 is manufactured
10 from materials having a low co-efficient of friction
11 then additional advantages in running in the hole
12 are also achieved. Notably, plastics, rubber and
13 zinc alloys give useful secondary advantages in this
14 respect.

15

16 The provision of the non-rotating bushing also
17 reduces drill string harmonics, and can help to
18 prevent differential sticking of the string.

19

20 Modifications and improvements can be incorporated
21 without departing from the scope of the invention.

Fig. 1.

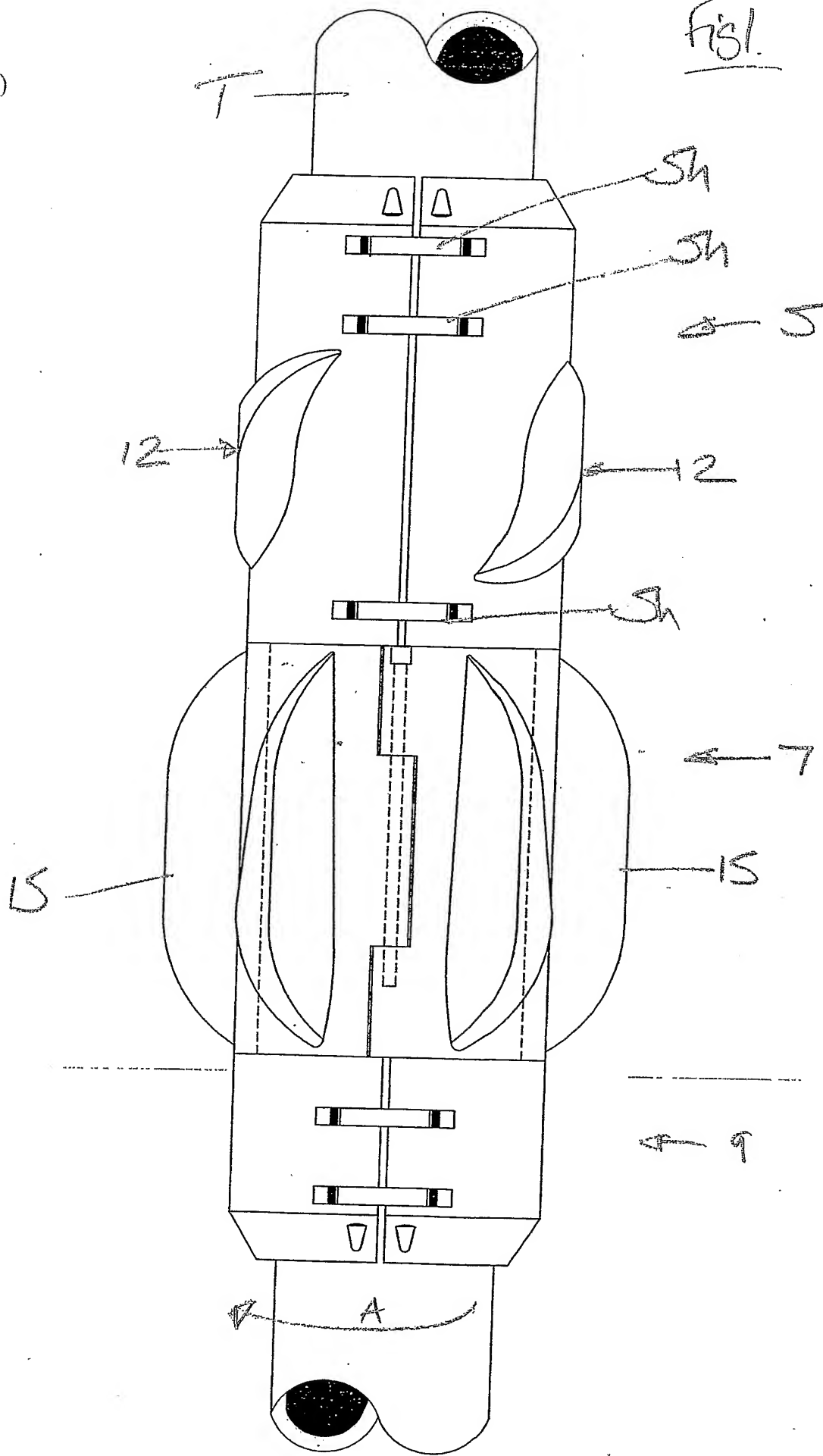


fig 2

3

12a

12

12m

12s

15u

15m

15L

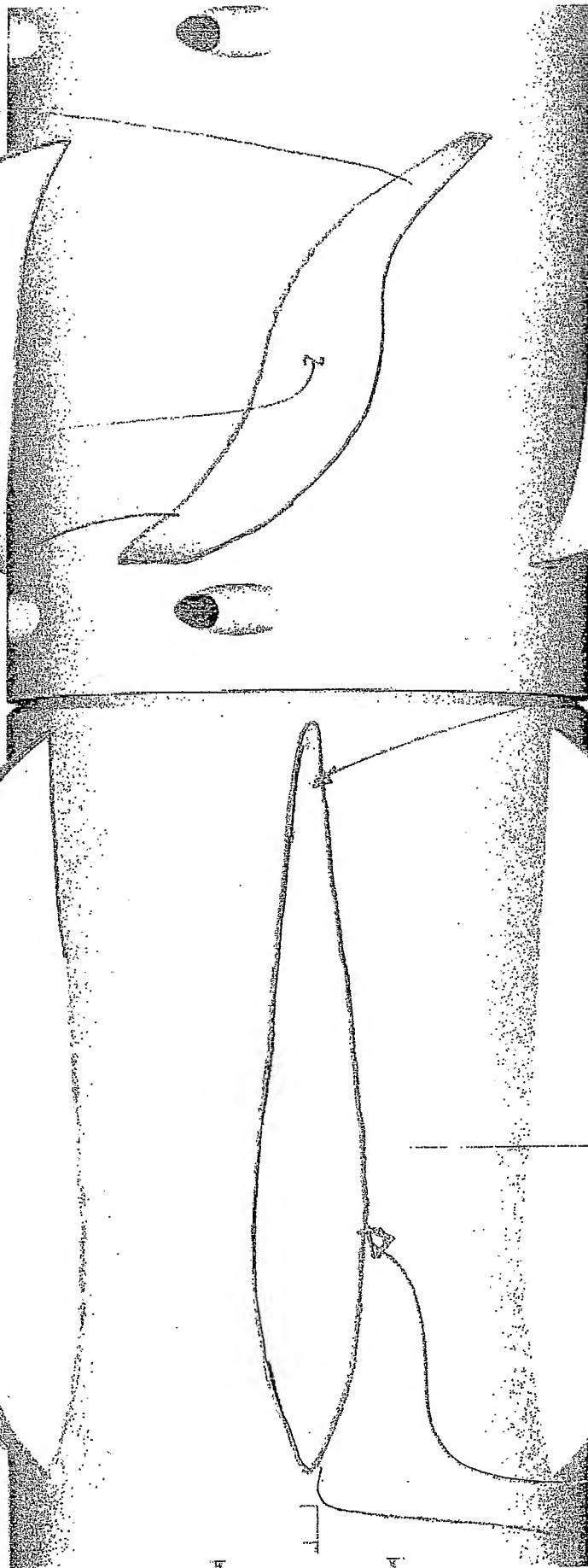
15u

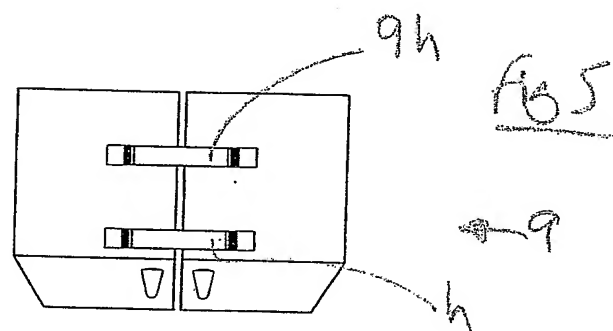
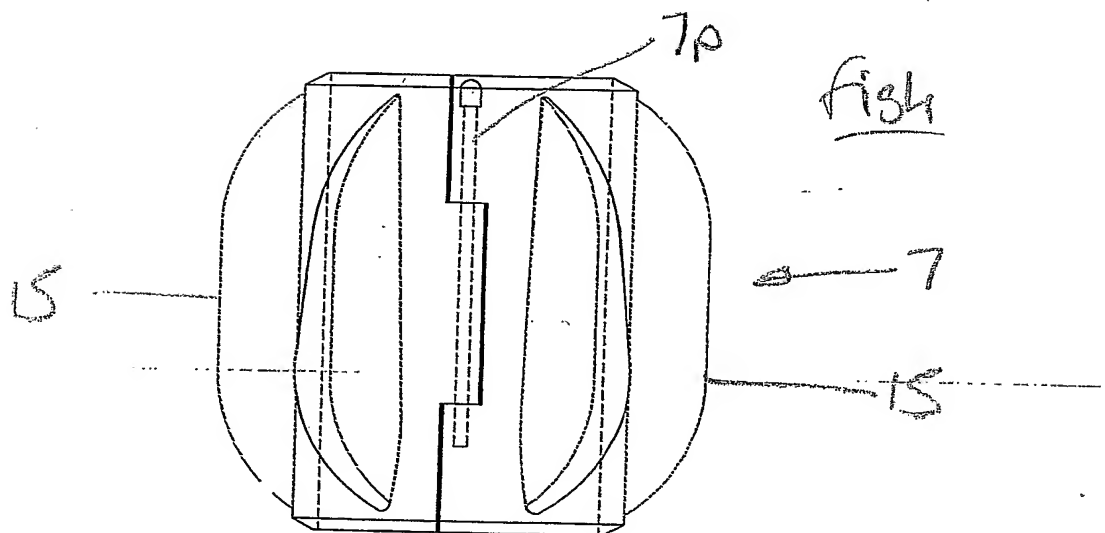
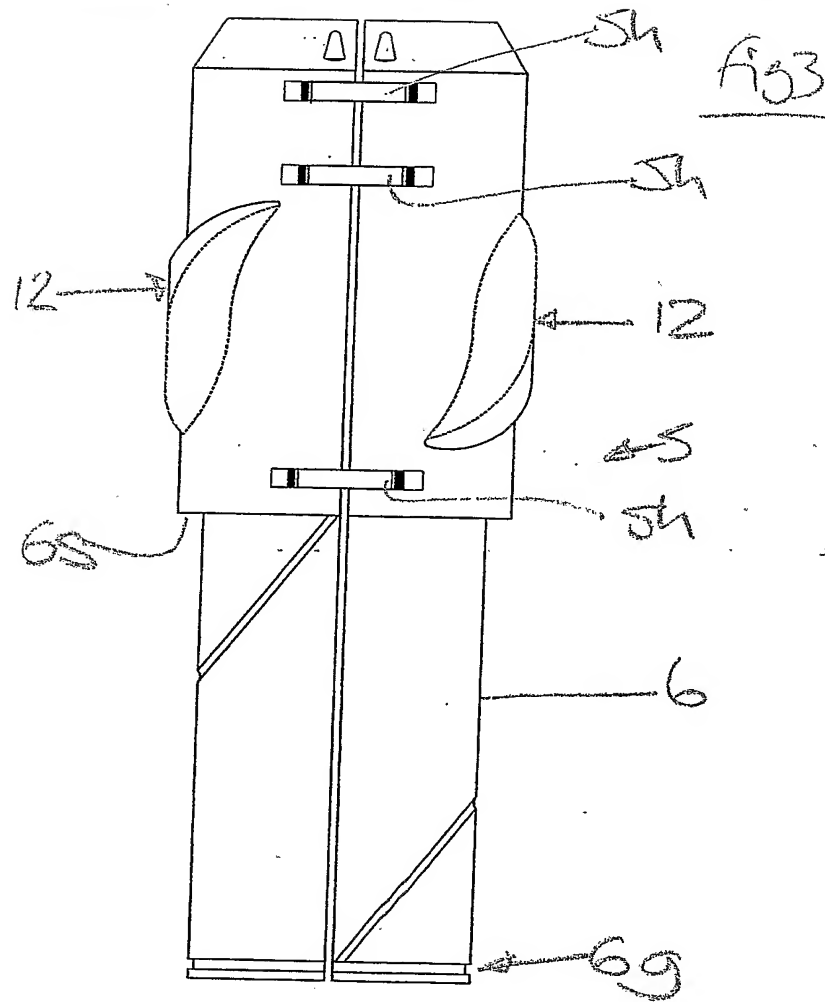
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15a

15d

7





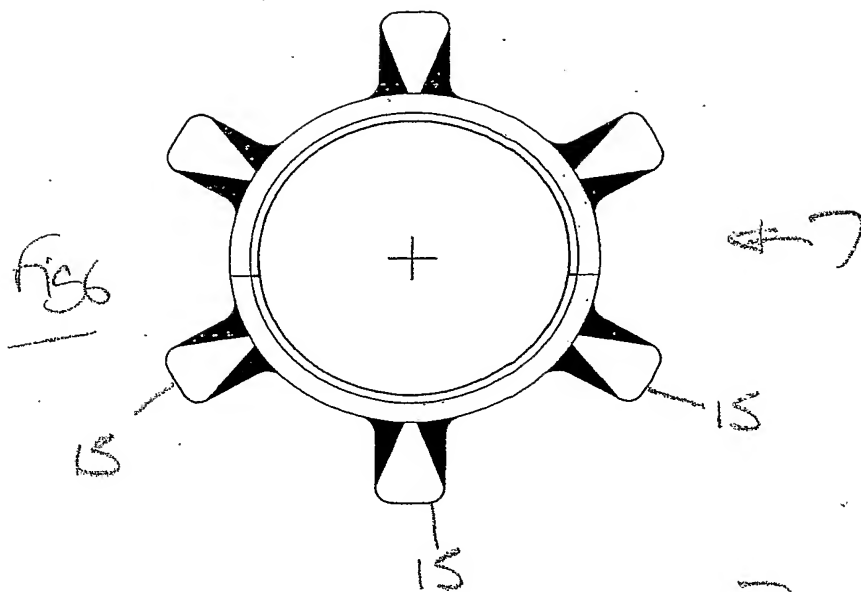


fig 8

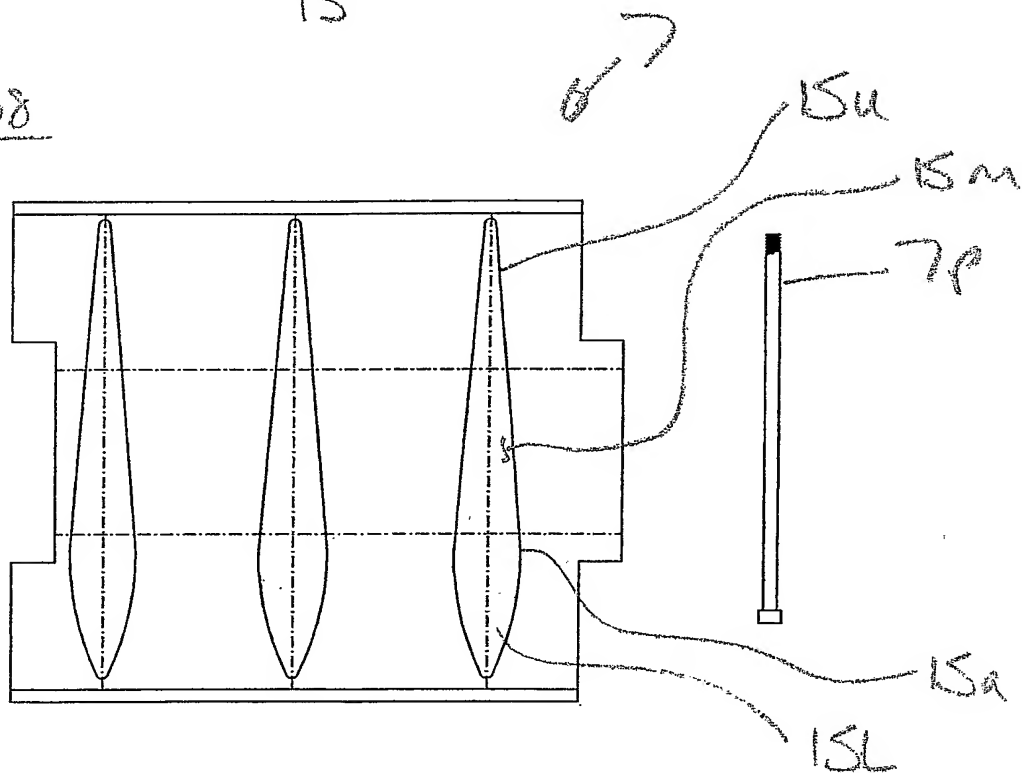


fig 7

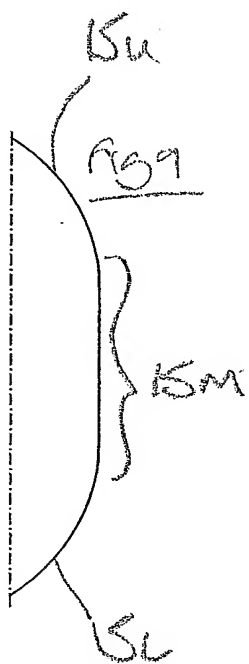
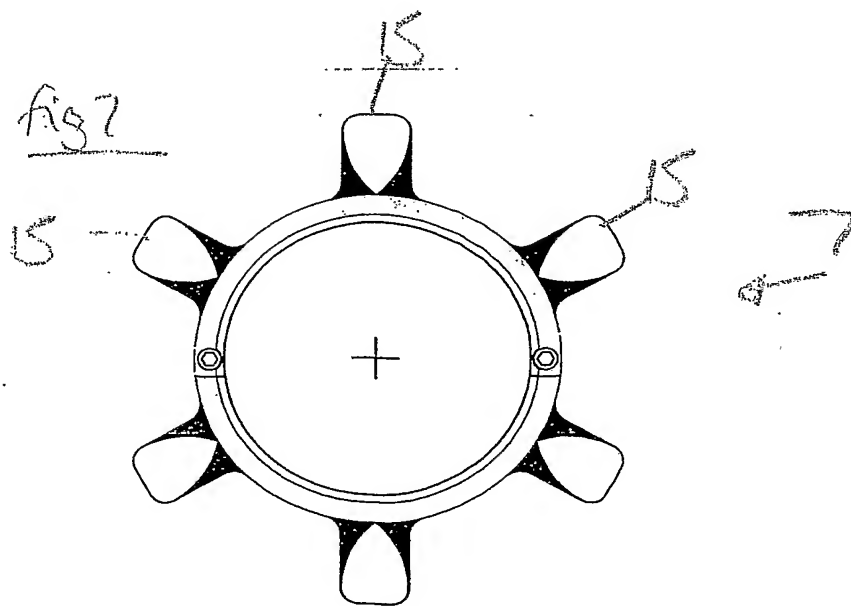


fig 10

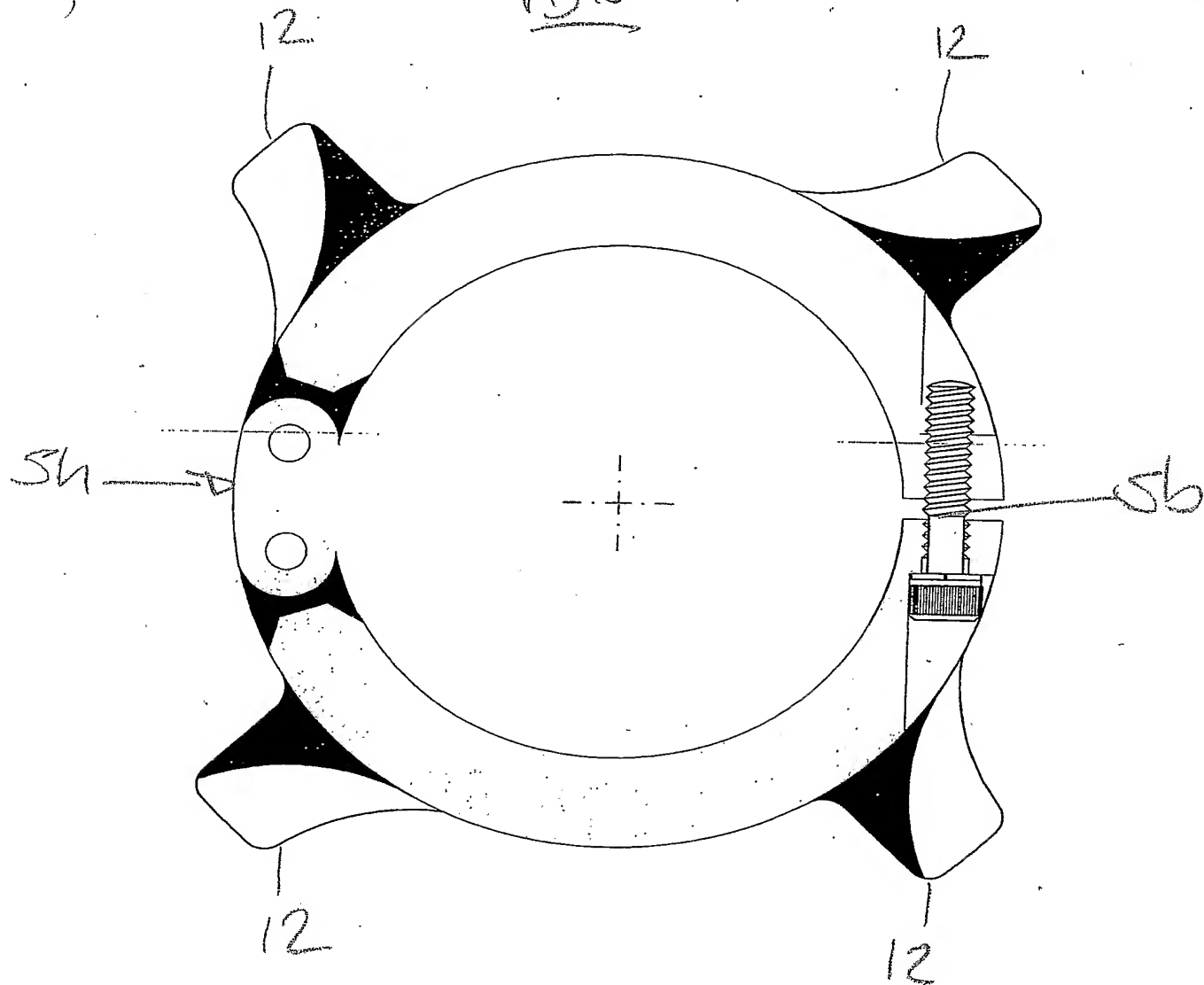
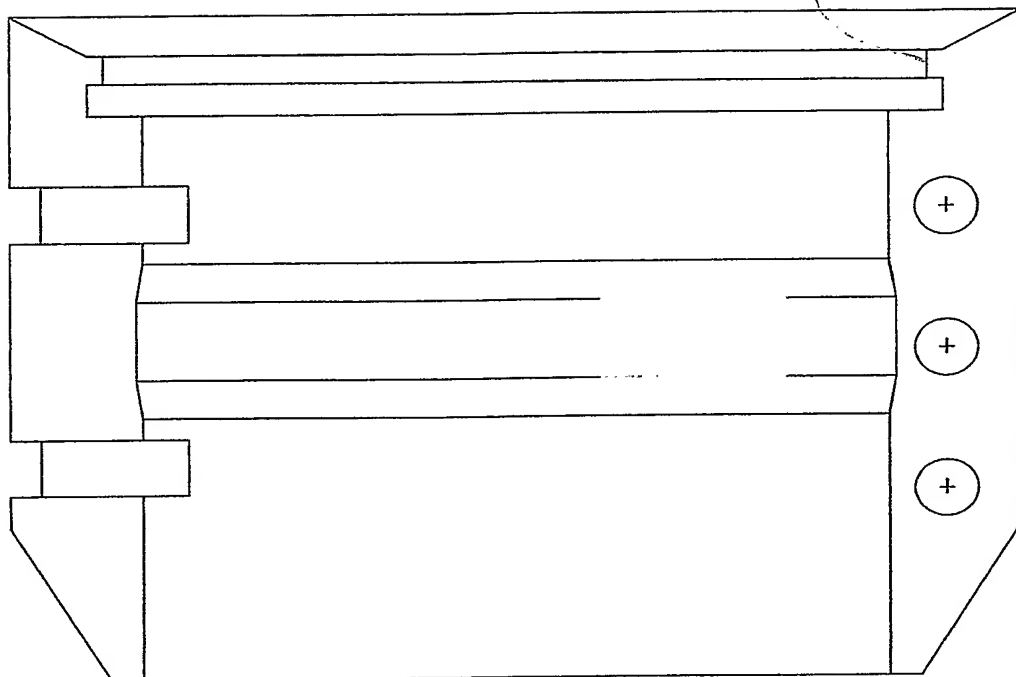
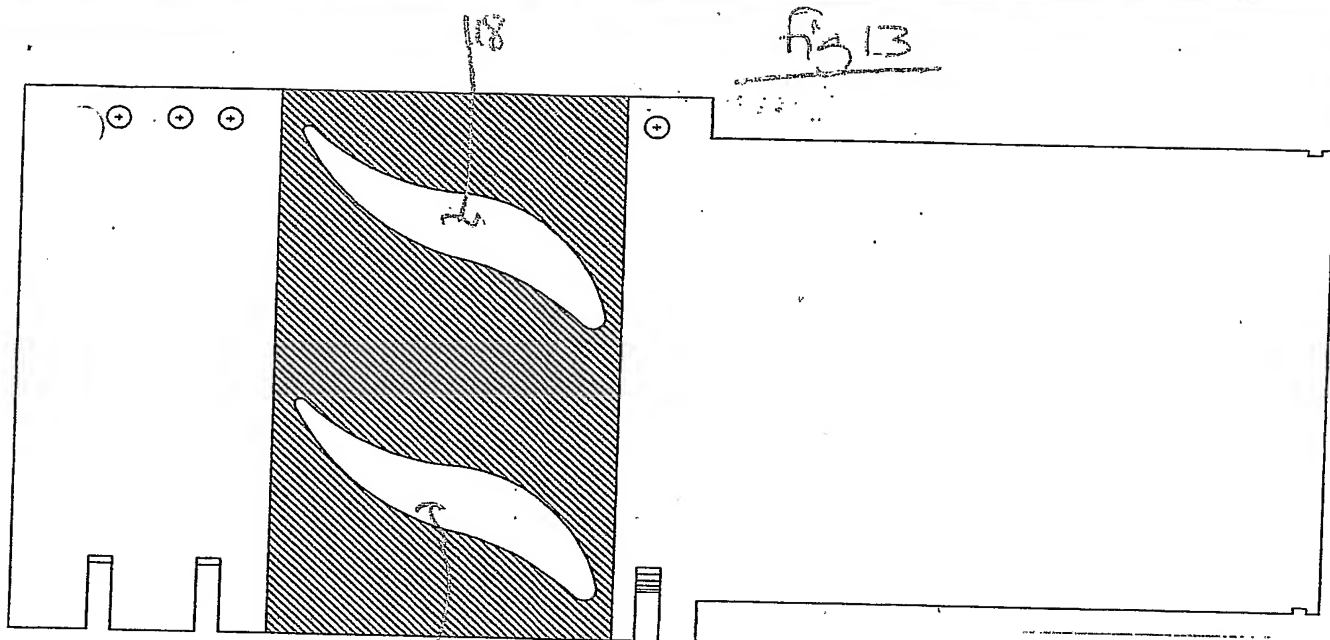


fig 11

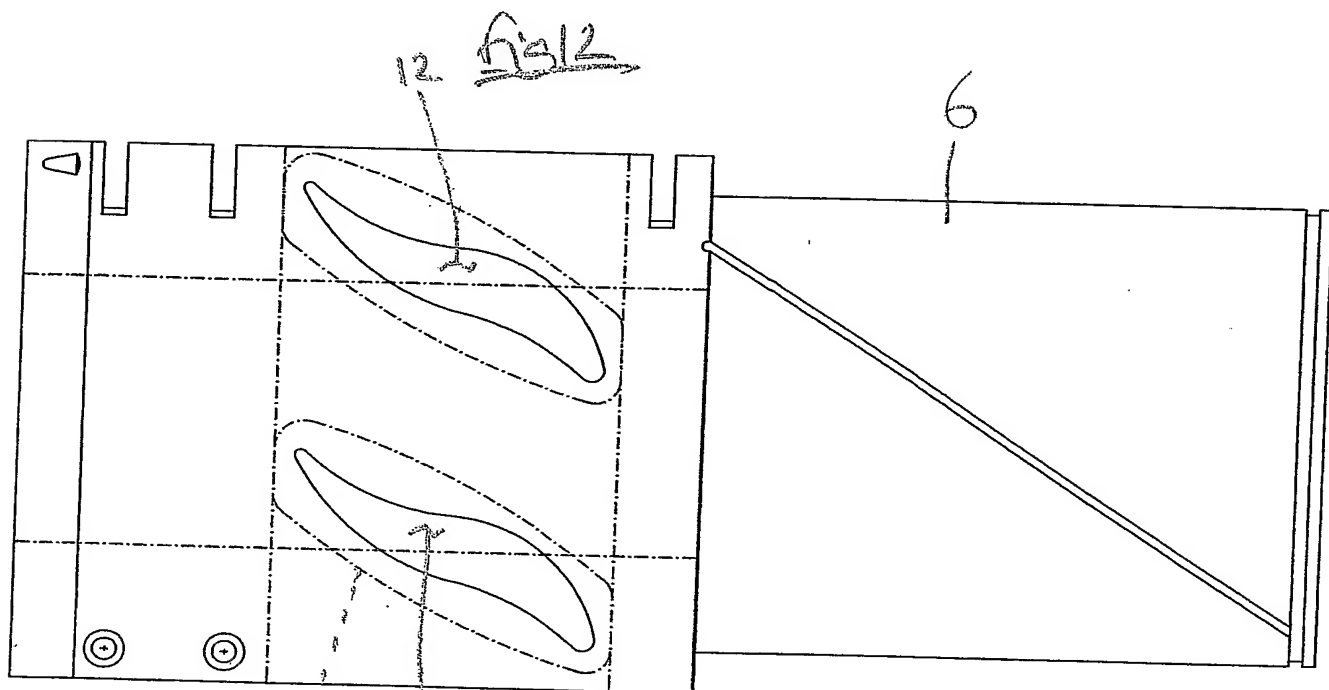
92



9



18- 5A



12b

12

5A

Fig. 1

